EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS, VOL. 26, 529–540 (1997)

DAMAGE STATISTICS OF 12 OCTOBER 1992 EARTHQUAKE IN THE GREATER CAIRO AREA

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SUMMARY

The paper describes the damage statistics of the 12 October 1992 earthquake (Dahshur earthquake) that hit the greater Cairo area in Egypt and measured 5.4 on the Richter scale. Building sample consisted of 2270 buildings distributed in almost every district in the greater Cairo area and their characteristics cover a wide range of date of construction and structural systems. Structural and non-structural damage to buildings are presented as functions of date of construction, height and type of construction.

It is believed that the information presented in the paper is of extreme importance to the engineering community as to the structural impact that the 1992 earthquake had on building stocks in the urban area. © 1997 by John Wiley & Sons, Ltd.

KEY WORDS: earthquake damage; damage statistics; Dahshur earthquake; load-bearing wall systems; RC skeleton systems; non-seismic damage

1. INTRODUCTION

In countries of low to moderate seismic activities such as Egypt, where earthquakes are infrequent phenomenon, the occurrence of an earthquake is regarded as a rare opportunity to professional communities involved in earthquake engineering to assess the seismic performance of different structures. In this regard, the recent earthquake of 12 October 1992 that hit the greater Cairo area and its vicinity, known as Dahshur earthquake, provided a unique and non-precedent opportunity as a full-scale testing experience of the heavily populated area and the wide spectrum of building stocks. A few number of reconnaissance reports were prepared by foreign teams[1,2] and a few studies on the response of specific structures[3,4] are available. There is a genuine need to examine this experience and extract the benchmarks of structural responses on a rational basis. The present paper is an attempt to analyse the data collected to throw light on the seismic performance of existing structures in Cairo area.

After the 12 October 1992 earthquake which caused extensive non-structural damage and moderate structural damage, a post earthquake damage assessment operation was undertaken by the Egyptian Engineering Syndicate (EES) and thousands of reports were compiled. Although the investigations were of a preliminary nature, the reports do contain invaluable information if they are properly and professionally processed. This was the motive for the present study in which data contained in the investigation reports are subjected to a computer-based statistical analysis with the objective of arriving at rationally based engineering statements regarding structural and non-structural damage. This exercise is commonly performed in foreign countries after every major earthquake. As for Egypt, the present study is the first and only technical effort to be undertaken for statistical analysis and judgment of an earthquake event.

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CCC 0098–8847/97/050529–12$17·50

Received 10 May 1996
Revised 15 October 1996

Table I. Geographical distribution of buildings sample

District code	Number of buildings
1	160
2	80
3	100
4	96
5	0
6	0
7	192
8	0
9	100
10	0
11	0
12	80
13	200
14	120
15	28
16	100
17	100
18	240
19	117
20	20
21	120
22	120
23	60
24	58
25	0
26	120
27	60
Total	**2270**

2. PROFILE OF BUILDING SAMPLE

In the present study, a sample of 2270 buildings is considered. They cover a wide spectrum of geographical distribution, date of construction and structural system properties as presented in the following profile analysis.

2.1. Geographical distribution

Geographically, buildings are all located in the greater Cairo area and distributed in almost all districts of Cairo. Geographical distribution of building sample is given in Table I and is shown schematically on the greater Cairo map in Figure 1.

2.2. Date of construction

Date of construction of building sample spans from late nineteenth century to very recent buildings of 1990. Distribution of building sample according to date of construction is shown in Figure 2. Buildings constructed before 1940 constitute about 20% of the sample and the next largest group is buildings of the seventies.

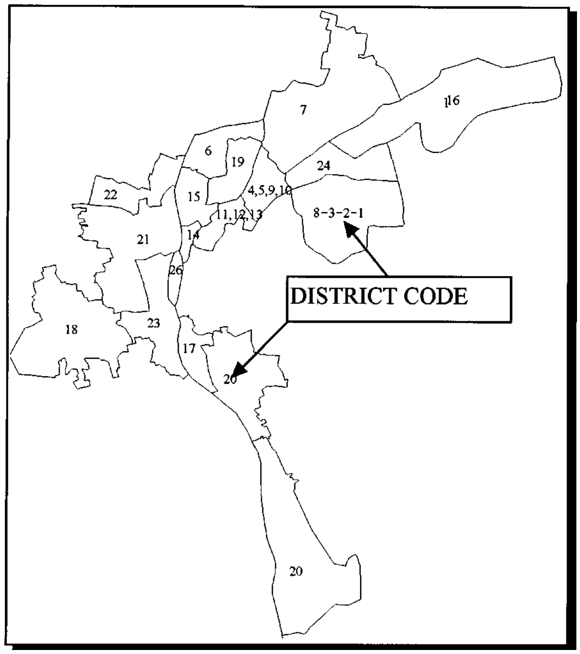

Figure 1. Map of greater Cario area

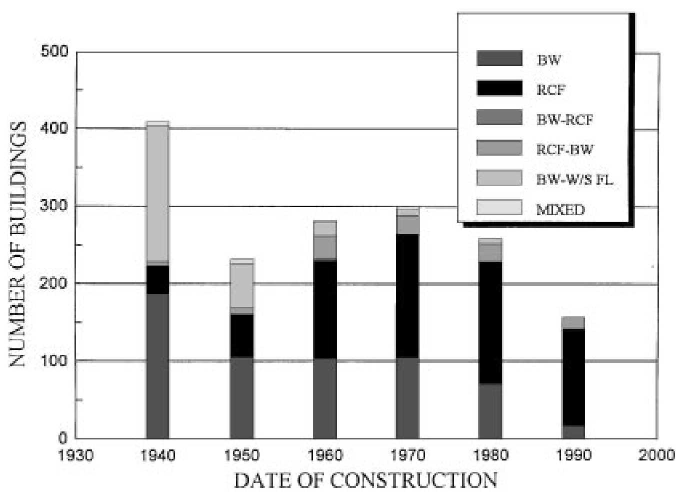

Figure 2. Distribution of building sample according to date of construction

2.3. Height

Distribution of building sample with respect to the height, being one of the influential discriminators of denoting damage, is shown in Figure 3. Four height groups are used according to the number of stories N, namely: (1) very low rise buildings with one or two stories, (2) low rise buildings with three to five stories, (3) medium rise buildings with six-to-ten stories, (4) high-rise buildings with more than ten stories. Buildings with three-to-five stories represent the majority of buildings sample and constitute almost 50% of the sample.

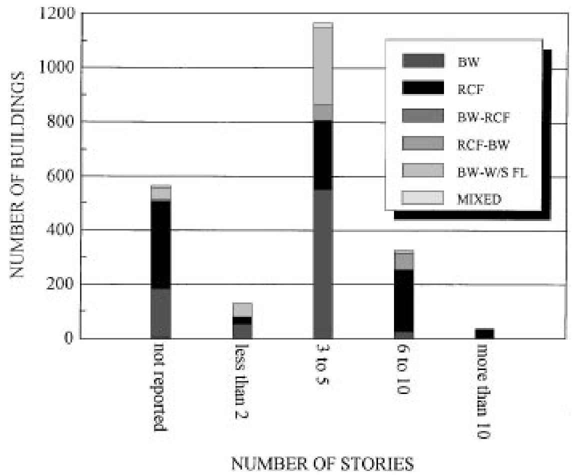

Figure 3. Distribution of building sample according to height

High-rise buildings are the lowest group in number and this confirms the observation that high-rise buildings behaved well in the earthquake.

2.4. *Structural systems*

Buildings are classified according to the type of structural system into six groups as follows.

1. *Bearing wall systems with reinforced concrete slabs* (*BW*) (824 buildings): This was the most common system in the thirties and forties using mainly stone blocks and non-cementitious mortars and it is still being constructed but using concrete blocks or bricks with cementitious mortars.
2. *Reinforced concrete skeleton* (*RCF*) (844 buildings): This is the most common system of construction which was introduced in Egypt in the forties and has been widely used ever since.
3. *Bearing wall system in lower stories and reinforced concrete skeleton in top stories* (*BW-RCF*) (4 buildings).
4. *Reinforced concrete skeleton in lower stories and bearing wall system in top stories* (*RCF-BW*) (132 buildings).
5. *Bearing wall systems with wood or steel floors* (*BW-W/S FL*) (385 buildings). Such buildings are put in a separate group because of the flexible nature of the floors and hence the box action cannot be maintained under lateral loads and they are expected to behave differently from bearing wall systems in the first group.
6. *Mixed bearing wall and reinforced concrete columns in plan* (*MIXED*) (31 buildings). This mixed system arises when a bearing wall building is extended in plan by adding reinforced concrete columns along the perimeter of the building and extending the slabs to connect the two supporting systems. Under lateral loads, walls and columns behave differently and connecting them leads to wall-column interaction.

3. STRUCTURAL DAMAGE

3.1. *Element level*

Damage observed in any of the structural elements (beams, columns, shear walls, bearing walls, and foundations) is characterized by the following.

(i) *Type of damage:* Varies depending on the element and for each element an associated list of damage types is provided. In columns, for example, damage type list is: (1) vertical cracks, (2) horizontal cracks, (3) diagonal cracks, (4) combined cracking, (5) local buckling of reinforcement.
(ii) *Severity of damage:* Depends on the width of cracks in the case of cracking symptoms. Three degrees of damage are proposed, viz., minor (hair cracks), moderate (intermediate widths), and severe (wide cracks or breakage).
(iii) *Spread of damage:* Describes the extent and location of damage and the following options are used: element damage is either confined to ground floor (or basement), confined to top stories, or appears in all floors.

3.2. *Building level*

The data of elements structural damage are employed to formulate the degree of structural damage of the whole building. Three degrees of building structural damage are synthesized as follows.

Severe damage: (If the elements structural damage jeopardize the integrity or the stability of the entire building). This arises when vertical supporting elements are seriously damaged. Specifically, if the degree of damage in columns or bearing walls is severe and damage appears in ground floors, then building structural damage is said to be severe.

Moderate damage: (If there is evident damage in structural elements but not to the extent to affect the integrity of the building and still structural repair is required). To describe the moderate state of building damage, the conditions of elements damage are logically related as follows:

Degree of column damage is ‘minor’ .OR.
Degree of beam damage is ‘severe’ .OR.
(Type of beam damage is ‘diagonal crack’ .AND. Degree of damage is ‘moderate’) .OR.
Degree of bearing wall damage is ‘moderate’ .OR.
(Degree of bearing wall damage is ‘severe’ .AND. Spread of damage is ‘confined to top stories’)

Minor damage: If there is no damage in the vertical elements, and only minor to moderate damage occurs in beams, the building damage is said to be *minor*.

3.3. *Structural damage vs height of buildings*

Figure 4 shows the number of buildings with structural damage of any degree, for each height group. Results are shown as percentage of the total number of buildings of each height group. It is evident that low-rise buildings received more structural damage than medium and high-rise buildings. This observation does not reflect the frequency content of the earthquake by as much as it reflects the aging and construction conditions associated with such low rise buildings. Going into more details of how these percentages break down in terms of degrees of structural damage, Figure 5 shows that most of these cases are of moderate degree.

3.4. *Structural damage vs date of construction*

Shown in Figure 6 is the variation of number of buildings containing structural damage, with date of construction. Results are presented as a percentage of the number of buildings having the same date of construction. Considering the upper-most curve which represents buildings with any degree of damage, one can read any point on the curve, say 1940, that 80% of all buildings constructed during 1940 experienced

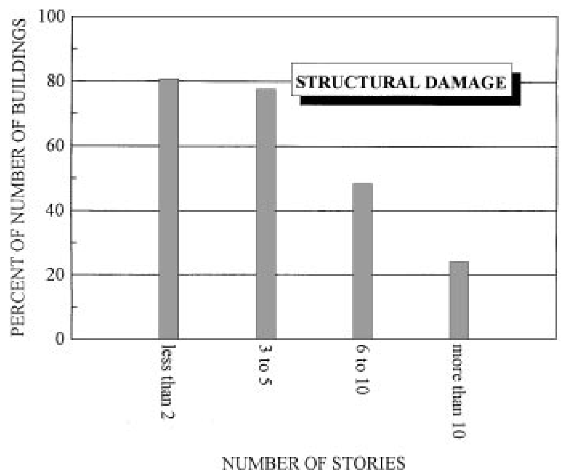

Figure 4. Distribution of structural damage according to height

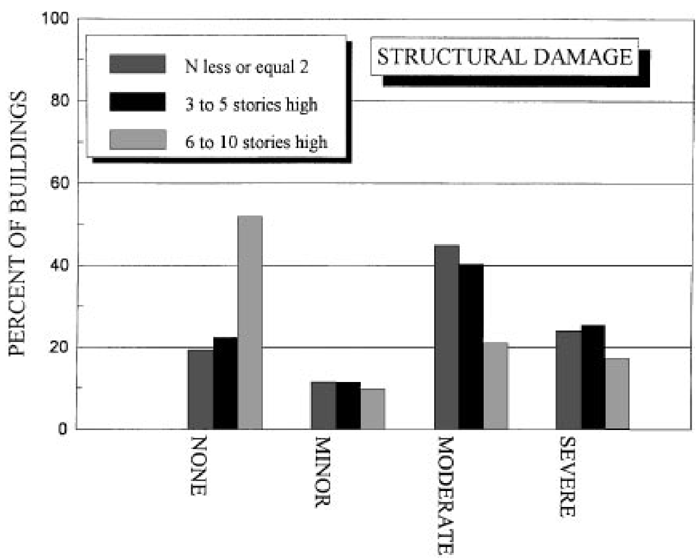

Figure 5. Distribution of severity of structural damage according to height

some structural damage. One can see that the percentage of structurally damaged buildings decrease as their date of construction becomes more recent. The other two curves show the same percentage but for severe and moderate degrees of structural damage. More useful information can be obtained if the percentages of structurally damaged buildings are presented for each type of structural system as shown in Figure 7. While for bearing wall systems the percentage decreases as buildings become more recent, reinforced concrete skeletal type shows an increase of damage percentage for recent buildings. Then, it can be concluded that older reinforced concrete skeletal buildings behaved better than recent ones under the effect of the earthquake.

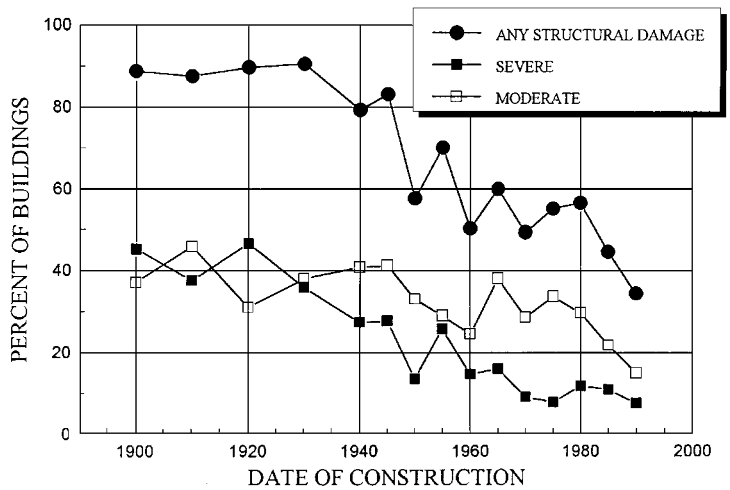

Figure 6. Variation of structural damage with date of construction

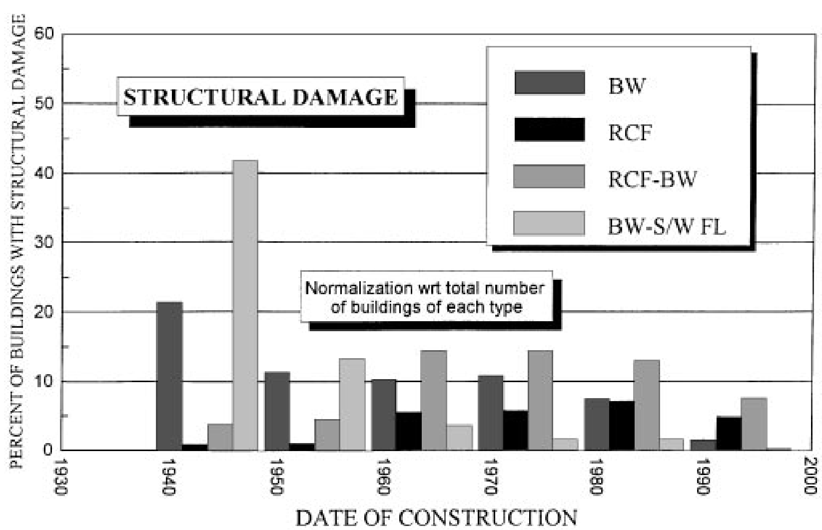

Figure 7. Distribution of structural damage according to date of construction and structural system

3.5. Structural damage vs type of structural system

Comparing the number of buildings either structurally damaged or not, for each type of structural system as shown in Figure 8, it can be seen that bearing wall systems received much more structural damage as compared to skeletal systems. By splitting the results to account for the degree of damage, as in Figure 9, it becomes clear that most of these cases of structural damages were of a moderate degree.

4. NON-STRUCTURAL DAMAGE

Damage in non-structural elements such as infill walls is characterized by its type (separation cracks at infill-RC frame interface lines, cracking in the infill panel) and the severity of damage depending on crack

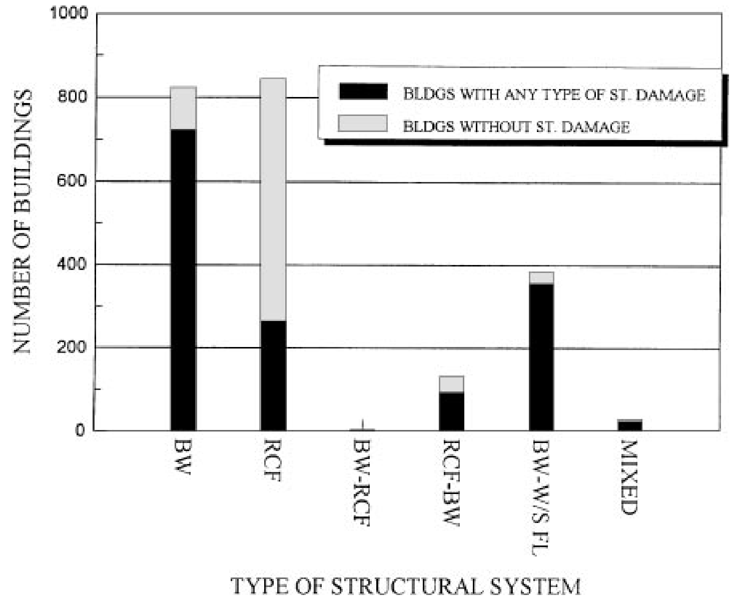

Figure 8. Distribution of structural damage according to type of structural system

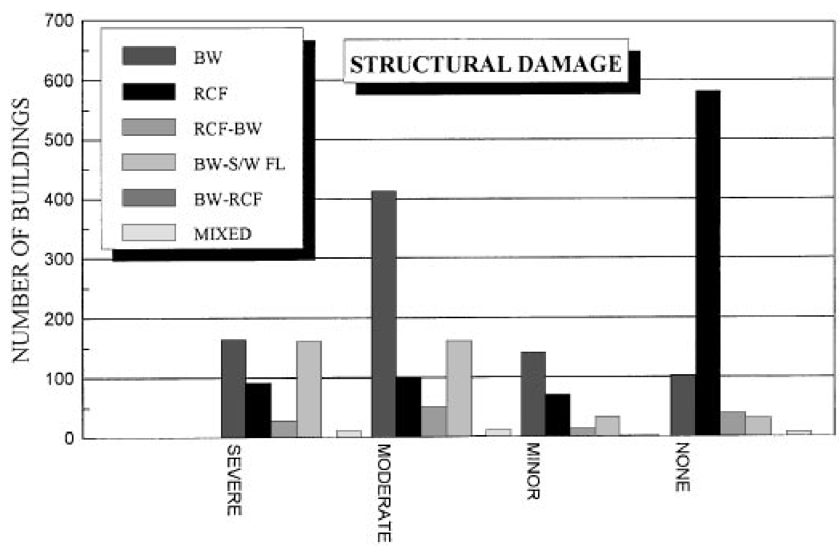

Figure 9. Distribution of severity of structural damage according to type of structural system

width. Figure 10 presents variation of infill damage of all types as a function of date of construction. Only moderate and severe cases of damage are considered in the study and cases of hair cracking are excluded. Highest percentage of buildings suffering from infill damage are those constructed during or before 1940, and the next largest is the recent buildings of 1990s, apparently because of the use of lighter blocks of low strength. As for the variation of infill damage with height of buildings shown in Figure 11, no definite conclusions can be drawn.

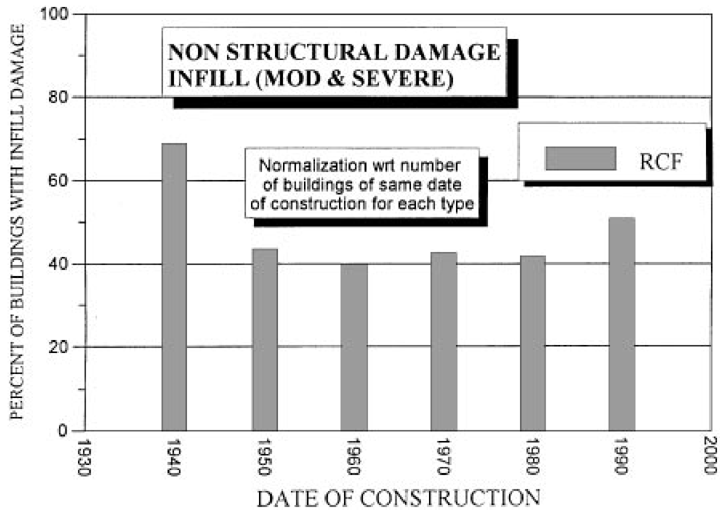

Figure 10. Distribution of infill damage (moderate & severe) according to date of construction

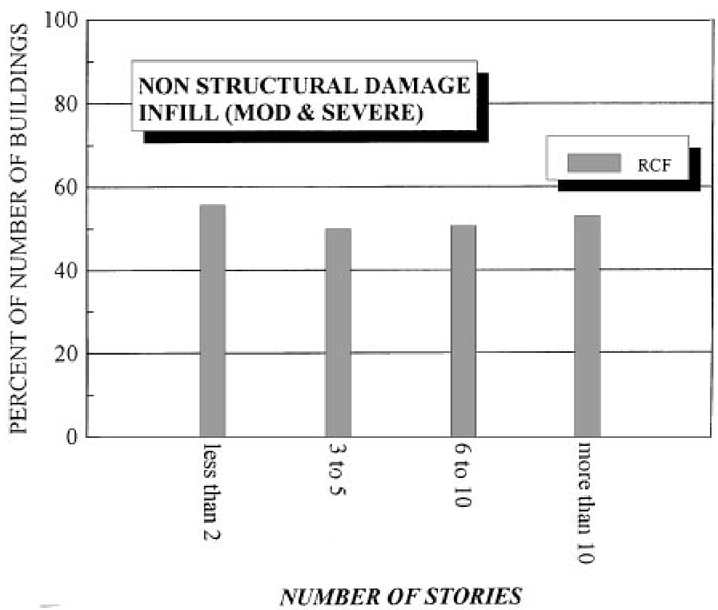

Figure 11. Distribution of infill damage (moderate & severe) according to height

5. NON-SEISMICALLY RELATED DAMAGE

The occurrences of the non-seismic defects are queried for each defect and they are arranged in a descending order in Figure 12 which shows the number of buildings in which any of these defects are encountered. It can be seen that the problem of corrosion of reinforcement is the most frequent defect in the present building sample. The next largest is the lack of insulation problem. Variation of these two defects is monitored with respect to date of construction of buildings and presented in Figure 13 in which number of buildings having the defect in any range of construction date is normalized using the total number of buildings having the

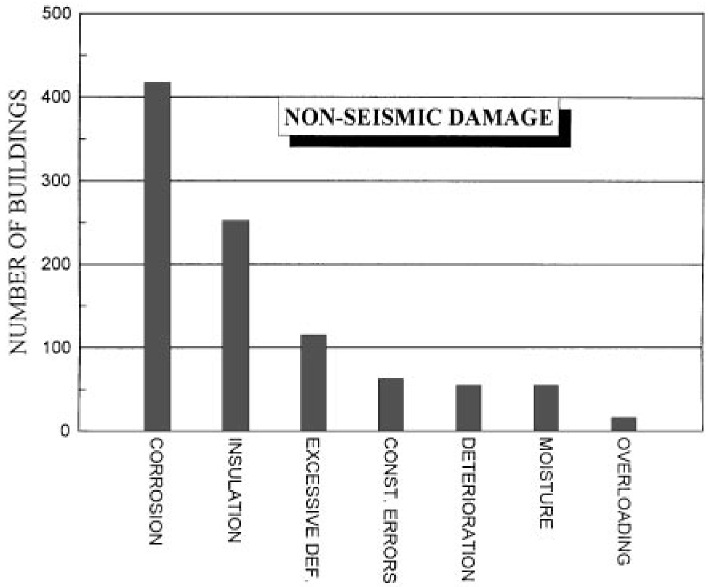

Figure 12. Distribution of non-seismic defects

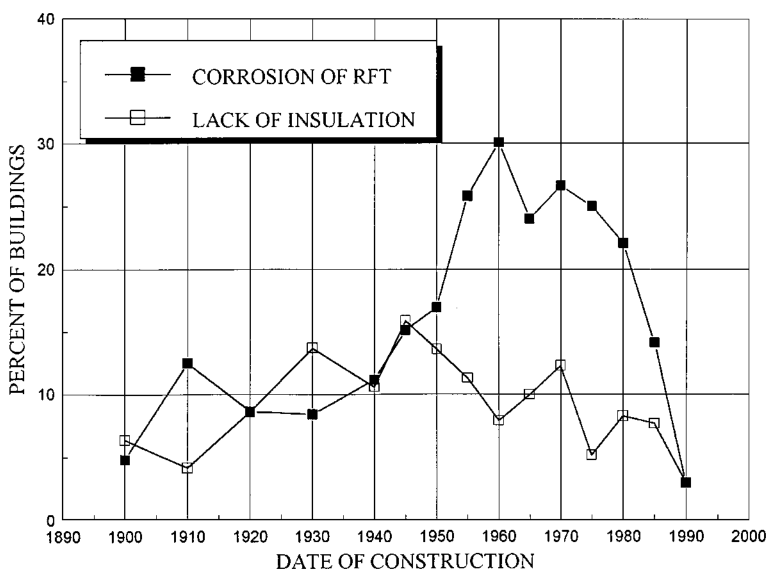

Figure 13. Distribution of corrosion and insulation defects according to date of construction

same construction date. While in older buildings of the forties or earlier, the percentage of buildings with corrosion problem is more or less 10 per cent, there is a definite increase of this percentage in more recent buildings of the fifties and beyond with the highest occurrence of the corrosion problem can be observed in the case of buildings of the sixties and seventies. Values of the percentage of corrosion-defected buildings decrease for very recent buildings of mid-eighties and nineties. The important lesson from this revealing

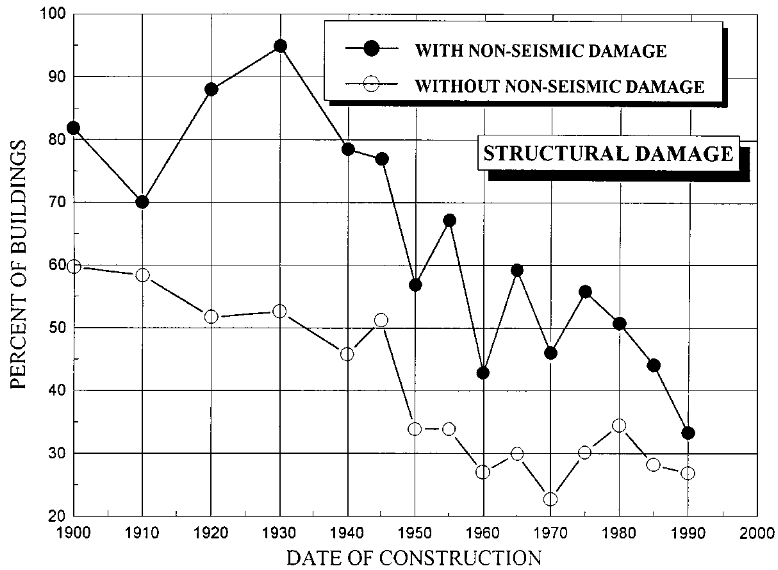

Figure 14. Distribution of structural damage in buildings with and without non-seismic defects

curve is that inferior materials and bad construction practices can be more detrimental to building durability than the aging effect.

The variation of the percentage of buildings having lack of insulation defect does not show a definite trend as the corrosion curve does.

Turning now to the critical issue of how these non-seismic defects which exist prior to the occurrence of an earthquake will affect the structural response of the defected building. To address this question, the percentage of buildings with structural damage in the non-defected group of buildings and for which non-seismic damage was not reported, is compared with the same percentage but for the defected group of buildings and for which non-seismic damage was reported. This comparison is shown in Figure 14 as a function of construction date. It can be clearly seen that, invariably, defected buildings received more structural damage than the non-defected buildings. The impact of non-seismic defects on structural capacity is reinforced by aging effect as can be seen from the larger difference between the two curves for the case of older buildings.

6. CONCLUSIONS

A sample of 2270 buildings located in the greater Cairo area, is selected for statistical analysis of damage inflicted by the 12 October 1992 earthquake. A computerized database management system is specifically developed to facilitate the entry, update, retrieve, and analysis of data. The study is the first to analyse data collected on the 1992 earthquake damage. In addition to the specific percentages of damage contained in the paper which give insight as to the seismic performance of different structures, the following conclusions are highlighted.

1. Low-rise buildings received more structural damage as compared to medium and high-rise buildings.
2. Reinforced concrete skeletal buildings behaved much better than bearing wall systems.
3. Infill damage was found to concentrate in very old and very recent buildings.

4. Corrosion of reinforcement was found to be the most frequent problem in the building sample with the highest occurrence rate in recent buildings of the seventies and eighties.
5. Non-seismically defected buildings suffered more structural damage as compared to non-defected buildings.

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